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REPORT ON THE MEETING OF THE PANEL ON CATHODIC PROTECTION OF UNDERGROUND STORAGE TANKS SEPTEMBER 11, 1987, CHARLOTTETOWN, PRINCE EDWARD ISLAND

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PHYSICAL METALLURGY RESEARCH LABORATORIES

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REPORT ON THE MEETING OF THE PANEL ON CATHODIC PROTECTION OF UNDERGROUND STORAGE TANKS

Charlottetown, Prince Edward Island
September 11, 1987

by

R.W. Revie

1. ATTENDANCE

Name	Affiliation
James T.N. Atkinson	Dept. of Metallurgical Engineering, Queen's University, Kingston, Ontario
Cecil C. Chappelow	Midwest Research Institute, Kansas City, Missouri
J. Ross Clendening	Consultant, Etobicoke, Ontario
Randall J. Galisky	Interprovincial Corrosion Control Company Limited, Burlington, Ontario
Robert Gummow	Corrosion Service Company Limited, Downsview, Ontario
Don Jardine	P.E.I. Dept. of Community and Cultural Affairs, Charlottetown, P.E.I.
Kelly Karr	Environment Canada, Ottawa
Eion MacKeigan	A.S.M. Corrosion Control, Edmonton, Alberta
Arnold G. Meyers	Clemmer Industries (1946) Ltd., Waterloo, Ontario
R. Winston Revie	Energy, Mines and Resources Canada, Ottawa
Hank St. Onge	Duratron Systems Limited, Scarborough, Ontario
David Webster	Commonwealth Seager Group, Calgary, Alberta

OBSERVERS

Sue Day	Environment Canada, Dartmouth, Nova Scotia
Art Hiscock	Environment Canada, Charlottetown, P.E.I.
Ron Hore	Ontario Ministry of the Environment, Sudbury, Ontario

John K. Lockwood	MFM Industries, Moncton, New Brunswick
L. Anne MacKinnon	Environment Canada, Dartmouth, Nova Scotia
Michael Must	Texaco, Willowdale, Ontario
N. Scrimgeour	New Brunswick Ministry of the Environment, Fredericton, New Brunswick
Gerry Stewart	P.E.I. Dept. of Community and Cultural Affairs, Charlottetown, P.E.I.
Bill Trussler	Shell Canada, Calgary, Alberta
Reg Wright	Underwriters' Laboratories of Canada, Scarborough, Ontario

2. INTRODUCTION

Mr. Karr introduced himself as the A/Head of the Oil and Gas Section at Environment Canada, which has a mandate to develop in cooperation with the provinces, territories and industry an Environmental Code of Practice for Underground Storage Tanks Containing Petroleum Products, under the direction of the Canadian Council of Resource and Environment Ministers. This Panel on cathodic protection of underground storage tanks was assembled to discuss some concerns expressed by tank owners with respect to the CAN4-S603.1 standard.

Mr. Karr noted that everyone on the Panel was donating his time for this meeting and expressed his appreciation for the commitment of the Panel members to this issue.

3. OBJECTIVES

Mr. Karr stated the objectives of the meeting:

1. To establish whether the CAN4-S603.1 code is adequate in all respects.

2. To establish whether some CAN4-S603.1 storage tanks not indicating -0.85 volt with respect to the $Cu/CuSO_4$ reference electrode are actually corroding.

3. The Panel should recommend how the CAN4-S603.1 code should be revised.

4. The Panel should define if and how existing installations not meeting the recommended potential measurement should be modified for corrosion protection.

5. To identify information gaps and areas of disagreement between panel members, and to suggest R&D that would lead to resolution of concerns.

4. CRITERION FOR CATHODIC PROTECTION

Mr. Gummow reviewed the criterion of cathodic protection - a potential of -850 mV with respect to the $Cu/CuSO_4$ reference electrode - and explained that it is based on a substantial amount of empirical data and field experience. He said that, depending on the relationship between corrosion rate and potential for the specific metal-soil combination, the corrosion rate may be negligible at potentials less negative than -850 mV, but in some other cases, potential must be more negative than -850 mV. In general, he said, the -850 mV criterion has been found to be satisfactory in relatively neutral pH soils without sulphate-reducing bacteria. There was a consensus at the meeting that the -850 mV criterion for cathodic protection is the one to use.

The steel tank industry uses a basic corrosion protection system that consists of excellent coatings and cathodic protection. In general, the industry uses the -850 mV criterion with current applied.

Mr. Gummow referred to three references:

(a) W.v. Baeckmann and W. Schwenk, Handbook of Cathodic Protection, translated from German by E. Neufeld and P. Neufeld, Portcullis Press, Redhill, Surrey, England, 1975.

(b) T.J. Barlo and W.E. Berry, A reassessment of the -0.85 V and 100 mV polarization criteria for cathodic protection of steel buried in soils, Proceedings, 9th International Congress on Metallic Corrosion, Toronto, June 1984, vol. 4, p. 86, Published by National Research Council of Canada, Ottawa; an assessment of the current cirteria for cathodic protection of buried steel pipelines, Materials Performance 23(9), 9 (1984).

(c) L. Krivian, "Application of the theory of cathodic protection to practical corrosion systems", British Corrosion Journal, 19(1), 34 (1984).

5. IR DROP

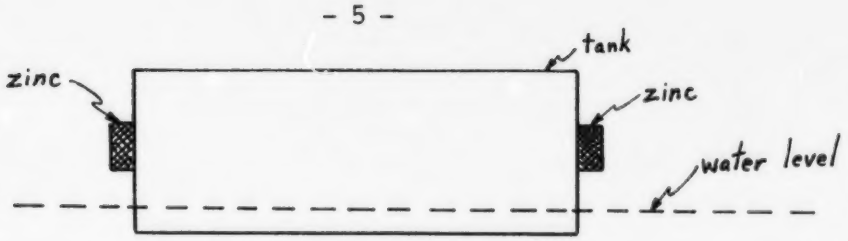
Measurement of potential may require a correction for IR potential drop. IR errors arise from current flow through the contact resistance at the reference electrode and through the resistances in the measuring circuit and in the soil. A high resistance voltmeter must be used for potential measurements so that IR drop is not significant in the measuring circuit. With impressed current systems, IR drop can be eliminated by turning off the current. With the sacrificial anodes bolted onto the tanks, it is impossible to stop the current flow. The potential measured is the potential of the controlling holidays on the coated surface. On a perfectly coated tank, the open circuit potential of the anodes would be measured.

Mr. Gummow expressed concern that a measured potential of -850 mV (not corrected for IR drop) is not sufficient to prevent corrosion if there is a substantial IR drop. For example, if the measured potential is -850 mV and the IR drop is 100 mV, then the true polarized potential is -750 mV, at which a significant corrosion rate may take place.

6. ANODES

It was agreed at the meeting that the design criteria be changed to protect tanks in soils of resistivity up to 15,000 ohm-centimetres.

Long, thin anodes have lower resistance than short, wide anodes, and the lower resistance results in higher current output. The zinc that is used is of purity about 99.99%. CAN4-S603.1 allows a maximum iron content of 0.003%, or 30 ppm, and it was agreed at the meeting that the 30 ppm content of iron in the zinc would not significantly affect the performance of zinc anodes.



The importance of having good electrical conductivity around the zinc anodes was noted. For example, if the zinc anodes are positioned in such a way that they are in dry soil above the level of the water table, as shown schematically in the above figure, then steel exposed at coating holidays on the bottom of the tank may be unprotected because of reduced anode current. The anodes should be soaked before the backfill is completed. The greater the number of anodes distributed over the tank, the more reliable the protection of the tank will be as the coating deteriorates over the 25-30 years following installation.

Mr. Gummow indicated that the backfill should contain two essential ingredients, bentonite and sodium sulphate, without which the zinc anodes will not function properly in low moisture conditions.

Each anode is connected to its tank with 2 bolts. Because some zinc anodes have been found without electrical connection to the tank, it is now recommended that it be mandatory for the manufacturer to carry out an electrical continuity check on all new tanks.

It was noted that the Steel Tank Institute standard requires approximately 2.5 times the weight of zinc that the ULC standard requires. The requirements of the CAN4-S603.1 standard for zinc plates are shown in Table 1, and those for the sti-P_3 specification are presented in Table 2. The weight of zinc required is defined on a different basis for the two specifications - on the basis of tank capacity for the CAN4-S603.1 and on the basis of tank surface area for the sti-P_3 specification. The tank surface areas presented in Table 1 are calculated from the tank dimensions presented in CAN4-S603.1.

TABLE 1 - Weight of Zinc Plate Anodes Required by CAN4-S603.1

Tank Capacity Litres	Tank Surface Area sq. metres	Minimum Total Anode Weight kgm
≤ 5,000	≤ 18.2	1.7
> 5,000, ≤ 15,000	> 18.2 ≤ 33.9	3.4
> 15,000, ≤ 25,000	> 33.9 ≤ 49.9	5.0
> 25,000, ≤ 75,000	> 49.9 ≤103.7	10.2
> 75,000, ≤125,000	>103.7 ≤159.4	17.0
>125,000, ≤175,000		20.4
>175,000, ≤250,000		27.2

TABLE 2 - Weight of Weld-on Zinc Anodes Required by sti-P_3 Specification

Tank Surface Area		Total Anode Weight	
Sq. Feet	Sq. Metres	lb.	kgm
≤174	≤16.2	10	4.5
175-475	16.3-44.1	20	9.1
476-950	44.2-88.3	40	18.1
951-1425	88.4-132.4	60	27.2
1426-1900	132.5-176.5	80	36.3
1901-2375	176.6-220.6	100	45.4
2376-2850	220.7-264.8	120	54.4

From comparing the required weights in Tables 1 and 2, it is apparent that, for the same size of tank, sti-P_3 requires a greater weight of zinc than CAN4-S603.1. The ratios of the required weights of zinc for a given tank surface area are presented in Table 3.

TABLE 3. Ratios of Weights of Zinc Required under sti-P_3 and CAN4-S603.1

Tank Surface Area sq. metres	Ratio
15	2.6
30	2.7
40	1.8
50	1.8
100	2.7
150	2.1

The possibility was raised of putting anodes on the sides of the tanks but it was agreed that the sides would be a poor location for anodes because of damage that would occur during shipping. The Steel Tank Institute sti-P_3 specification requires anodes on the shell (i.e., side) as well as on the heads if the tank length is more than 35 feet.

It was concluded that more current is essential in some situations to obtain the required early full protection of -850 mV vs. $Cu/CuSO_4$. It was recommended that all tanks have at least two anodes, as opposed to the one anode that the smaller tanks are now required to have. In addition, it was recommended that anode length be doubled, compared with what is now used, to compensate for very high soil resistivity conditions.

Electrical isolation of the tank is essential. If the tank is not electrically isolated, the anode could then be connected with the whole electrical grounding system, thereby making any cathodic protection ineffective because of insufficient current. The specific effect of connections to other systems depends entirely on what is connected.

7. COATINGS

The quality of the coating is important. If the coating has been damaged and there are numerous holidays, the current will take the path of least resistance, with the result that some holidays may not be protected. In addition, increased output of the anodes will result in reduced anode life. Soil movement may cause coating damage.

It was reported that two tanks in P.E.I. had been returned to the manufacturer when the coatings were found to be unsatisfactory. Coating inspection before installation is essential. A patch kit is supplied with each tank so that scratched or uncoated areas can be patched - if the patch kit contains insufficient material to rectify the problem areas, the tank is returned.

There was some discussion of coating damage by hydrogen that could form as a result of overprotection with magnesium anodes, but no agreement on this issue was reached.

8. POTENTIAL MEASUREMENTS

In Prince Edward Island, new regulations have recently been developed, and CAN4-S603.1 is being used, as it is in most parts of Canada. Mr. Jardine reported that, notwithstanding the usage of this standard, there have been numerous problems in P.E.I. in achieving the potential of -850 mV vs. $Cu/CuSO_4$.

Dr. Chappelow commented that fines may apply in the United States if the -850 mV criterion is not achieved.

Potential measurements taken in P.E.I. the day before the meeting were discussed. One tank, where the measured potential was -727 mV, either had no anode or the anode was not making contact. It appeared from the measurements made that sufficient cathodic protection was not being applied to this tank to meet the criterion. On this size of tank (4,500 L), only one anode is used.

One of the panelists stated that the installer should check on continuity just before the backfill is put in, and it was agreed at the meeting that this should be done. When a tank is installed the installer should measure and record the potential. Because of the specialized nature of these tanks, the installer should be required to take a course on tank installation, in which the corrosion protection system is explained.

The problem of obtaining the potential reading indicative of full protection was discussed. After installation of tanks, the difference between the measured potential of a tank with incomplete protection and the required potential tends to decrease, but the time to attain full protection may be excessive. The panel agreed that the protection potential should be achieved within three months after installation. One panelist commented that soaking the anodes with water before completing the backfill would alleviate this problem. The CAN4-S603.1 standard requires that each anode be dampened with water during backfilling.

One of the panelists, Mr. MacKeigan, had carried out a study in which the potentials of 603.1 tanks installed in the last five years were measured; about 45% of these tanks had potentials less than -850 mV vs. $Cu/CuSO_4$. The same firm had carried out another study on tanks of all ages, some installed before 1974; of these tanks, 78% were not protected according to the potential criterion.

Another firm had observed that 10-15% of zinc-protected tanks have low potential readings, even in the case of tanks in the ground for two years or more.

Another panelist reported that his firm frequently replaces zinc anodes with magnesium anodes, but it was noted that when magnesium-protected tanks are taken out of service, the magnesium is usually gone, indicating that the lifetime of the magnesium sacrificial anode had been exceeded.

It was agreed that, to facilitate accurate potential measurements, holes should be drilled through the pavement and plastic insert plugs should be installed through the asphalt or concrete to the soil over the centre of each tank.

A suggestion was made that each tank should have a zinc reference electrode attached at the factory with the appropriate wire connection. It was agreed at the meeting that this would present an additional complication and an additional wire with the possibility of shorting to something else.

9. LEAKS

Mr. Wright asked how many 603.1 tanks have actually leaked because of external corrosion. The response was that, of the 34,000 listed 603.1 tanks, none have leaked because of external corrosion. The absence of leaks, of course, does not indicate an absence of corrosion. Mr. Gummow reported one tank failure caused by internal corrosion, and Mr. Clendening indicated two more tank failures caused by internal corrosion.

10. NEXT MEETING

It was agreed that another meeting of the Panel should be held. Mr. Karr set the date of Thursday, January 21, 1988 and indicated that the venue would be in Toronto. Because some members would be unable to attend on this date, the meeting was subsequently re-scheduled for January 28, 1988. This meeting will be held at the Holiday Inn, Toronto Airport.

11. CONCLUSIONS OF THE PANEL MEETING

1. The criterion for cathodic protection is the potential measurement of -850 mV with respect to the $Cu/CuSO_4$ reference electrode.

2. In some installations, there is a problem in initially achieving this potential, and the difference between the measured potential and the required potential is greatest immediately after installation.

3. To obtain the required potential, larger zinc anodes must be used so that the capacity for increased current will be available; alternatively, magnesium anodes may be used.

4. All tanks must have at least two anodes.

5. To facilitate accurate potential measurements, holes should be drilled through the pavement and plastic insert plugs should be installed through the asphalt or concrete to the soil over the centre of each tank.

6. Protection must be achieved, as indicated by a potential reading of at least -850 mV with respect to $Cu/CuSO_4$, within three months after installation.

7. Installers of tanks should be required to complete a training course on tank installation, in which the corrosion protection system is explained.

8. A coating examination must be carried out before installation and necessary repairs must be made.

9. Installers of tanks must check the anodes and tanks for electrical continuity immediately before installation, and tanks must not be installed unless continuity has been established.

BIOGRAPHIES OF PANEL PARTICIPANTS

James T.N. Atkinson, P.Eng.

James Atkinson is Associate Professor of Metallurgical Engineering at Queen's University, Kingston, Ontario. He obtained a B.Eng. and M.Sc. from McGill University and a Ph.D. from the University of Toronto. He worked with the Corrosion Section at Defence Research Establishment (Atlantic) from 1952-1962 and served on the RCN Committee on Corrosion and Fouling. Since 1962 he has been engaged in teaching and research at Queen's University, with corrosion and applied electrometallurgy as the principal field of activity. He is a former Director and Chairman of the Education Committee of NACE and is the co-author of the text Corrosion and Its Control, An Introduction to the Subject, with H. Van Droffelmar.

Cecil C. Chappelow, Ph.D.

Dr. Chappelow has 35 years experience in contract research and development including about 20 years in technical management at Midwest Research Institute. As Program Manager, Polymers and Coatings, he coordinates and manages the research activities of a group of organic chemists and polymer scientists conducting projects for a variety of industrial clients, trade associations and government agencies. Programs conducted under his direction have included: corrosion-protective coatings for underground and marine pipelines; moisture-resistant adhesives for composite structures; fiberglass-reinforced thermoplastics for pile driver cushions; new methods for in-plant testing of fusion bonded epoxy pipeline coatings; utilization of organotin polymers in marine antifouling coatings; extruded composite polyethylene coated linepipe for actic use; and external corrosion control of buried steel pipeline within steel casings. Currently, he is involved in a program for the Office of Underground Storage Tanks (OUST) in the U.S. EPA. Dr. Chappelow is the author/co-author of numerous technical papers and is the coinventor of 14 patents on chemical products and processes. He received his B.A. degree from the University of Southern California, and his M.A. and Ph.D. degrees from the University of Missouri.

J. Ross Clendening, P.Eng.

From 1955 to 1986, Mr. Clendening worked with Imperial Oil Limited in the Marketing Department where, for many years, he was responsible for all tank and fitting designs used at all of ESSO's marketing facilities in Canada. The ESSO Automotive Service Centres were all designed and built under Mr. Clendening's direction. He led a 6-month Canada-wide study in 1977 on leaking underground storage systems for the Petroleum Association for Conservation of the Canadian Environment (PACE). From 1979 until he retired in 1986, Mr. Clendening directed a 10-year upgrading program based on tank age and soil aggressiveness at 3500 underground storage sites across Canada. In 1985 and 1986, he was the PACE technical advisor assigned to develop new

regulations for underground petroleum systems for the four Atlantic provinces. Mr. Clendening now works as a consultant on petroleum storage and handling facilities.

Randall J. Galisky

Randall Galisky is employed with Interprovincial Corrosion Control Company Limited as a Corrosion Engineer. He has managed a number of corrosion control programs for underground storage tank systems. Other work he has been involved in includes the prevention of pipeline corrosion by cathodic protection and isolation, research and development in electrolytic grounding, and the effects of A.C. interference on cathodically protected structures. He is currently Publicity Executive for the Toronto Section of NACE. In 1987 he was an instructor at the Appalachian Underground Corrosion Course at West Virginia University in West Virginia. He received a B.Sc. degree in Chemical Engineering at the University of Calgary.

Bob Gummow, P.Eng.

Bob Gummow is Vice-President of Engineering at Corrosion Service Company Limited where he has been employed since 1962. He obtained a diploma in Natural Gas Technology from Ryerson Institute of Technology in 1962 and a B.A.Sc. in Electrical Engineering from the University of Toronto in 1968. He is a corrosion specialist as certified by the National Association of Corrosion Engineers (NACE), a certified instructor of the NACE Cathodic Protection course, which he has taught since 1978, and is co-author of the revised cathodic protection course. Since 1985 he has been a member of the NACE "Blue Ribbon" committee T-10-1 on criteria and has been responsible for evaluating and referencing all pertinent literature on cathodic protection criteria. In 1978 he produced the "Guideline Specification for the Impressed Current Method of Cathodic Protection of Underground Service Station Tankage" for the Petroleum Association for the Conservation of the Canadian Environment (PACE) and in 1986 revised this specification which has been reissued as PACE Report #87-1.

Kelly Karr, P.Eng.

Mr. Karr is Acting Head of the Oil and Gas Section of Environment Canada. He is responsible for the federal underground storage tank program and is the coordinator of the National Task Force on Leaking Storage Tanks developed under the auspices of Canadian Council of Resource and Environment Ministers. Mr. Karr is the principal author of the Environmental Code of Practice for Underground Storage Tanks Containing Petroleum Products, which will be published in 1988. He acts as the facilitator for the Panel discussions. Mr. Karr received the B.Sc. degree in civil engineering from the University of Alberta.

Eion L. MacKeigan, P.Eng.

Eion MacKeigan is Manager of Engineering and Operations for A.S.M. Corrosion Control, A Division of Oilfield Electronics (Estevan) Ltd. He obtained a B.Eng. from Nova Scotia Technical College. He managed a number of corrosion control projects regarding planning and implementation of cathodic protection systems for private and government owned corporations and oil related industries. Specialization includes corrosion control of buried fuel storage tanks, oil production flowlines and well casings, plant site underground piping systems and steel reinforcement/embedment in concrete structures. Memberships include The Association of Professional Engineers, Geologists and Geophysicists of Alberta, A.P.E.G.G.A.; The Association of Engineers of Saskatchewan, A.P.E.S.; The National Association of Corrosion Engineers, N.A.C.E.

Arnold G. Meyers

A product and equipment designer, inventor and a holder of several patents with direct management and manufacturing involvement for more than 40 years with committee and association involvement for as many years. Chairman of the Board of Clemmer Industries (1964) Limited, a tank and vessel manufacturer in Waterloo, Ontario. Chairman of the ULC Task Group #2 for the ULC S600A committee for the Standards for Hazardous Liquid Storage Tanks since 1978, member of CGA B 149 committee for Propane Tanks, CSA B66 committee for Sewage Tanks, National Fire Code Standing committee, CSA B623 committee selection - storage - handling - and transport of dangerous goods, CSA B620 B621, and B622 Highway Tanks and Portable Tanks for transport of dangerous goods. Past director of Steel Tank Institute (USA), secretary of Steel Tank Association of Canada from its inception in 1975, director of Canadian Heat Exchanger and Vessel Manufacturers Association. Member of Precision Metalforming association, Metal Spinning Division (U.S.A.). Recipient of an Iron Ring from the Wardens of University of Toronto in recognition for self study and achievements in mechanical engineering and related fields such as welding, galvanic corrosion protection systems, hydraulic electrical and pneumatic automation epuipment.

R. Winston Revie

Winston Revie is Head of the Corrosion Science Section in the Physical Metallurgy Research Laboratories, Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada, Ottawa. He is co-author with H.H. Uhlig of Corrosion and Corrosion Control, 3rd edition, a university textbook on corrosion. He was Chairman of the International Conference on Pipeline Inspection held in Edmonton in 1983. Dr. Revie has carried out corrosion R&D for over 20 years, since graduating from McGill University with a Bachelor of Engineering degree in metallurgical engineering. His post-graduate studies were at Rensselaer Polytechnic Institute, where he obtained a Master of Engineering degree in materials engineering, and at Massachusetts Institute of Technology, where he completed the Ph.D. He did postdoctoral research at the Flinders University of South Australia and at the Australian National University before returning to Canada in 1978.

Henri S. St. Onge (Hank)

Hank St. Onge is President of Duratron Systems Limited, a company engaged in cathodic protection services and pipeline rehabilitation. Hank has over 25 years experience in the underground corrosion field with expertise in pipeline, fuel storage tanks, waterworks and construction practice. He serves on numerous committee associations including ASTM, ULC, STAC and AWWA. Hank has written many papers on corrosion and cathodic protection, is an active member of NACE and has served as Chairman for the Toronto section. Hank as an inventor holds 5 patents on cathodic protection devices and pipeline rehabilitation techniques.

R. David Webster, P.Eng.

David Webster is a partner and Manager of Engineering for the Commonwealth Seager Group in Edmonton. He is responsible for corporate performance for a broad range of activities in cathodic protection and corrosion. His areas of specialization include cathodic protection design for pipelines, buried underground structures and well casing networks, mitigation of induced A.C. in pipelines, mitigation of stray D.C. interference, cathodic protection of steel in concrete, and marine cathodic protection. From 1975-1980, he was NACE representative on ULC Committee S-600A for Buried Steel Fuel Storage Tankage. He is a member of NACE Group Committee T-10 on Underground Corrosion Control and of NACE Group Committee T-1 on Corrosion Control in Petroleum Production. He obtained a B.A.Sc. degree in mechanical engineering from University of Toronto.